PRELIMINARY FUEL CONSUMPTION GUIDELINES FOR PRESCRIBED BURNING IN ONTARIO SLASH FUEL COMPLEXES

D.J. McRAE

GREAT LAKES FOREST RESEARCH CENTRE

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Information Office,
Great Lakes Forest Research Centre,
Canadian Forestry Service,
Department of the Environment,
Box 490,
Sault Ste. Marie, Ontario.
P6A 5M7

ABSTRACT

This report provides interim fuel consumption guidelines for five common slash fuel complexes found in Ontario. Slash fuel consumption and depth of burn were found to be related to preburn fuel loadings, and to fire weather as expressed by the Buildup Index (BUI), a component code of the Canadian Forest Fire Weather Index (CFFWI). The use of these guidelines for prescribed burn planning is discussed.

RÉSUMÉ

Le présent rapport fournit des directives provisoires sur la consommation de combustibles relativement à cinq complexes de déchets combustibles se trouvant communément en Ontario. Une relation a été établie entre d'une part la consommation de déchets combustibles et la profondeur de brûlage et d'autre part les accumulations de combustibles antérieures aux brûlages et les conditions météorologiques propices aux incendies en termes d'Indice d'accumulation (I.A.), lequel entre dans la composition de l'Indice canadien Forêt-Météo (ICFM). L'utilisation de ces directives dans la planification des brûlages dirigés est discutée.

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INTRODUCTION

The Canadian Forest Fire Danger Rating System has two component parts: the Canadian Forest Fire Weather Index (CFFWI) (Anon. 1978) and a series of Fire Behavior Indices (FBIs). The former is on a relative scale while the latter are expressed in absolute values.

The CFFWI is a measure of fire danger based on a series of fuel moisture codes. In general, personnel using the CFFWI rate fire danger and behavior higher or more extreme in a relative sense as the codes and indices of the CFFWI increase. This rating provides an important technique for planning presuppression action for any period of the fire season.

Fire behavior characteristics, an important consideration when one is fighting forest fires, can be determined for specific fuel complexes through the use of FBIs developed for that fuel type. Some of these fire behavior characteristics are fuel consumption, depth of burn, rate of spread, and frontal fire intensity as they relate to the codes and indices of the CFFWI. FBIs are currently being developed for a number of Ontario fuel complexes, in both standing timber and logging slash.

A Burning Index for jack pine logging slash was issued in 1972 as Supplement ONT-1 to the CFFWI (Stocks 1972), and has served as a basis for developing prescriptions for most prescribed burns planned by the Ontario Ministry of Natural Resources (OMNR) over the past seven years. This index, now referred to as an FBI, provided fire management personnel with a means of estimating the codes and indices of the CFFWI required to meet burn objectives set by timber personnel.

Initially, FBIs were intended for use in estimating all fire behavior characteristics for important Ontario fuel types. For slash complexes, the FBI format is modified to deal only with specific fire behavior parameters such as fuel consumption and depth of burn. Estimates of rates of spread and frontal fire intensities for slash complexes are somewhat meaningless since they are based to a large degree on the ignition pattern chosen for the prescribed burn (McRae et al. 1979). This uncertainty generally precludes the use of these parameters in an FBI designed for prescribed burning in slash fuels, and as a result the tables contained in this report refer only to fuel consumption and depth of burn.

In previous years, Ontario fire management personnel working in slash fuel complexes other than jack pine used the Supplement ONT-1 tables as a rough approximation of fire behavior in conifer slash in general, as no definitive information was available for other slash fuel types. Recently a large amount of data has been gathered on OMNR prescribed burns and this information has been used in this report to produce interim fuel consumption guidelines for prescribed burning in jack pine and four additional fuel types.

PROCEDURE AND ANALYSIS

Personnel from the Great Lakes Forest Research Centre (GLFRC) engaged in prescribed fire research collected preburn and postburn fuel data on a number of OMNR operational prescribed burns during the 1977 and 1978 seasons. Fuel sampling of slash was done according to a modified version of Van Wagner's (1968) line intersect sampling method as outlined in McRae et al. (1979). Both preburn and postburn fuel samples were taken along the same sample triangles to provide estimations of slash consumption. Depth-of-burn measurements were taken according to McRae et al. (ibid.) in conjunction with slash measurements. Data were collected for five common logging slash fuel types found in Ontario: jack pine (*Pinus banksiana* Lamb.), jack pine mixedwood, lowland black spruce (*Picea mariana* [Mill.] B.S.P.), upland spruce and balsam fir (*Abies balsamea* [L.] Mill.) slash (see Tables 5a-9a for slash description).

A standard regression equation in the form $Z = a + bx + cy$ was used for predicting slash consumption. In this equation

Z = slash consumption (kg/m^2),
x = preburn slash fuel loadings (kg/m^2),
y = Buildup Index (BUI) of the Canadian Forest Fire Weather Index, and
a,b and c are constants for a given slash type and diameter size class.

Values for coefficients and correlation coefficient (R) values are given in Table 1.

Two equations were developed for each slash fuel complex, one for fine and medium slash fuels (0-6.99 cm) and one for large slash fuels 7.0 cm and greater. This was done since the degree of fuel consumption of a particular slash fuel piece should be determined largely by fuel moisture content (y, Buildup Index) and fuel size (the ratio of surface area to volume for each fuel piece). Larger pieces should dry and be consumed more slowly because their ratios of surface area to volume are lower than those for smaller pieces.

A standard linear regression equation in the form of $Z = a + by$, satisfying the equation $Z \leq x$, was used for predicting depth of burn. In this equation

Z = depth of burn (cm),
x = preburn duff depth (cm),
y = Buildup Index (BUI) of the Canadian Forest Fire Weather Index, and
a and b are constants for a given duff type.

Values for coefficients and correlation coefficient (R) values are given in Table 2.

Table 1. Coefficient for slash consumption equations by slash fuel type and diameter size classes.

Slash type	Diameter size class (cm)	Coefficients			
		a	b	c	R
Jack pine	0-6.99	+0.0086	+0.5406	+0.0046	0.80
	≥ 7.0	-0.3416	+0.2687	+0.0082	0.85
Jack pine mixedwood	0-6.99	-0.2793	+0.9256	+0.0134	0.93
	≥ 7.0	-0.4121	+0.2669	+0.0262	0.71
Lowland spruce	0-6.99	-0.6166	+0.9527	+0.0088	0.89
	≥ 7.0	-0.1519	+0.2454	+0.0054	0.72
Upland spruce	0-6.99	-0.5255	+0.8158	+0.0134	0.96
	≥ 7.0	+0.0370	+0.1914	+0.0130	0.56
Balsam fir	0-6.99	0.0000	0.0000	+1.0000	----
	≥ 7.0	-2.6900	+0.5862	+0.0838	0.89

Table 2. Coefficients for duff consumption equations by duff type.

Duff type	Coefficients		
	a	b	R
Jack pine	+0.8240	+0.1521	0.77
Jack pine mixedwood	+0.5881	+0.1946	0.67
Lowland spruce	+0.8525	+0.0888	0.68
Upland spruce	-7.9948	+0.3244	0.64
Balsam fir	+2.1537	+0.0651	0.46

Preburn duff depth was not considered in the equation, because duff dries only from its top surface downward and its moisture content is a result of previous weather conditions. Therefore, potential depth of burn estimated by this method will be greater than is actually possible when the fuel moisture becomes sufficiently low for the bottom duff layers to be involved in the combustion process. Users should realize that depth of burn cannot exceed the duff depth ($Z \leq y$), and the maximum estimated depth of burn obviously cannot exceed total duff depth. In this way, preburn duff depth enters the estimate as a restraint.

The fuel consumption guidelines described are preliminary and are based on only a few experimental research plots representing a small range of possible preburn conditions and Buildup Indices (Tables 3 and 4). Future research will reduce the extrapolation necessary in this report.

FUEL CONSUMPTION TABLES

Results from Tables 1 and 2 were used in the construction of 11 tables for estimating fuel consumption and depth of burn. The purpose of these tables is to provide the prescribed burn planner with results obtained in this report so that he can develop the prescribed burn prescription. Tables 5a to 9b present slash consumption estimates for all slash fuel types. Part (a) of each table represents the 0-6.99 cm diameter size class while part (b) represents slash fuels 7.0 cm and greater in diameter. Table 10 provides data for estimating depth of burn for any of the five slash fuel type sites on the basis of the BUI in effect at the time.

The estimates are based on a BUI calculated at the burn site at 1300 hours on the day of the prescribed burn. Somewhat lower estimates can be expected for morning or evening burns when the relative humidity is much greater than that measured at 1300 hours.

To use the slash consumption tables (5a-9b), one chooses the correct table for the slash fuel common to the prescribed burn site, then by interpolation from preburn slash loadings and BUI, one determines the potential slash consumption for the prescribed burn site. The estimate for slash consumption is made separately for slash between 0 cm and 6.99 cm [part (a) of each table] and slash 7.0 cm and greater in diameter [part (b) of each table]. Total slash consumption can be estimated by adding these two estimates together. Depth of burn estimates are made by choosing different ranges in the BUI for a particular duff fuel type (Table 10). To ensure that the prescribed burn plan based on the data in these tables is realistic, fire personnel in Ontario should make certain that the depth of burn is not greater than the preburn duff depth; to ensure that the fire weather prescription for a given prescribed burn is realistic, they should use computer program PBWX (Martell 1978). A description of the five common logging slash fuel types is included with the tables to provide a means of selecting the correct tables.

Table 3. Ranges in slash consumption, preburn slash loadings, and Buildup Index (BUI) used in developing coefficients found in Table 1.

Slash type	Diameter size class (cm)	Range in slash consumption (kg/m^2) (Z)	Range in preburn slash loadings (kg/m^2) (x)	Range in BUI (y)	No. of burns	No. of observations
Jack pine	0-6.99	0.67- 1.75	0.67- 2.43	20-38	3	9
	≥ 7.0	0.06- 1.89	0.27- 5.60	7-38	3	11
Jack pine mixedwood	0-6.99	0.41- 3.54	0.34- 3.54	7-37	5	56
	≥ 7.0	0.12- 3.24	0.37-10.79	7-37	5	56
Lowland spruce	0-6.99	0.31- 4.04	1.00- 4.41	7-61	5	28
	≥ 7.0	0.02- 2.22	0.22- 7.32	7-61	5	28
Upland spruce	0-6.99	0.40- 2.94	0.20- 2.96	16-61	5	22
	≥ 7.0	0.08- 3.10	0.14-10.36	16-61	5	19
Balsam fir	0-6.99	0.67- 3.01	0.67- 3.01	27-46	3	10
	≥ 7.0	0.78-13.80	0.78-18.31	27-46	3	10

Table 4. Ranges in depth of burn and Buildup Index data used in developing coefficients found in Table 2.

Duff type	Range in depth of burn measured (cm) (Z)	Range in BUI (y)	No. of burns	No. of observations[a]
Jack pine[b]	0.89-3.23	15-59	24	24
Jack pine mixedwood	0.27-9.15	7-37	5	46
Lowland spruce	0.00-6.40	7-42	5	25
Upland spruce	3.36-6.55	37-42	5	8
Balsam fir	3.18-7.15	27-46	3	6

[a]Each observation is an average of 5 depth-of-burn values except for jack pine which is an average of 27 to 60 measurements (Stocks and Walker 1972).

[b]Data obtained from Stocks and Walker (1972).

The tables predicting slash fuel consumption and depth of burn will serve as a useful guide in the preburn planning stage of a prescribed burn. These two variables are usually given as objectives for the burn and these objectives will determine the BUI required to achieve burn objectives. Example 1 makes use of fuel consumption and depth-of-burn tables as described in this report for estimating the BUI range of the prescribed fire prescription.

Example 1. The use of fuel consumption and depth-of-burn tables for estimating the BUI range of the prescribed fire prescription.

The following table shows a number of possible outcomes for a site with an average jack pine slash fuel loading of 1.727 and 3.873 kg/m^2 for the 0-6.99, and 7.0 cm and greater size classes respectively, burned under different BUI conditions.

	BUI			
	11-19	20-24	25-29	30-34
Slash consumption (kg/m^2)[a] 0 - 6.99 cm	1.024	1.056	1.079	1.102
Slash consumption (kg/m^2)[b] ≥ 7.0 cm	.722	.779	.820	.861
Total slash consumption (kg/m^2)	1.746	1.835	1.899	1.963
Depth of burn[c] (cm)	3.11	4.17	4.93	5.69

[a]obtained from Table 5 (a).

[b]obtained from Table 5 (b).

[c]obtained from Table 10.

If a forest manager wished to remove a duff layer 4.5 cm deep in order to prepare a seedbed, the fire manager would find, in checking this table, that his prescription ought to have a BUI in the range of 25-29 or greater. Similarly, if he wished to remove at least 60% of the fine to medium slash fuels (0-6.99 cm) his prescription, without taking into account duff removal, would require a BUI in the range of 20-24 or greater.

Table 5

SLASH TYPE: Jack pine

DESCRIPTION: This slash type is easily distinguished by the fact that it consists almost entirely of jack pine slash, usually as a result of cutting in even-aged jack pine stands.

(a). Estimation of slash consumption (kg/m^2) for jack pine slash pieces 0-6.99 cm in diameter.[a]

	Preburn slash loading (kg/m^2)								
BUI	0-0.99	1.0-1.49	1.5-1.99	2.0-2.49	2.5-2.99	3.0-3.49	3.5-3.99	4.0-4.99	4.5-4.99
0-10	0.302	0.707	0.978	1.248	1.518	1.789	2.059	2.329	2.599
11-19	0.348	0.753	1.024	1.294	1.564	1.835	2.105	2.375	2.645
20-24	0.380	0.786	1.056	1.326	1.596	1.867	2.137	2.407	2.678
25-29	0.403	0.809	1.079	1.349	1.619	1.890	2.160	2.430	2.701
30-34	0.426	0.832	1.102	1.372	1.642	1.913	2.183	2.453	2.224
35-39	0.449	0.855	1.125	1.395	1.665	1.936	2.206	2.476	2.747
40-44	0.472	0.878	1.148	1.418	1.688	1.959	2.229	2.499	2.770
45-49	0.495	0.901	1.171	1.441	1.711	1.982	2.252	2.522	2.793
50-54	0.518	0.924	1.194	1.464	1.734	2.005	2.275	2.545	2.816
55-59	0.541	0.947	1.217	1.487	1.757	2.028	2.298	2.568	2.839
60-64	0.564	0.970	1.240	1.510	1.780	2.051	2.321	2.591	2.862
65-69	0.587	0.993	1.263	1.533	1.803	2.074	2.344	2.614	2.885
70-74	0.610	1.016	1.286	1.556	1.826	2.097	2.367	2.637	2.908
75-79	0.633	1.039	1.309	1.579	1.849	2.120	2.390	2.660	2.931
80-84	0.656	1.062	1.332	1.602	1.872	2.143	2.413	2.683	2.954
85-89	0.679	1.085	1.355	1.625	1.895	2.166	2.436	2.706	2.977
90-100	0.716	1.121	1.392	1.662	1.932	2.203	2.473	2.743	3.013

(continued)

Table 5 (concluded)

(b). Estimation of slash consumption (kg/m^2) for jack pine slash pieces 7.0 cm or more in diameter.[a]

	Preburn slash loading (kg/m^2)								
BUI	0-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	5.0-5.99	6.0-6.99	7.0-7.99	8.0-8.99
0-10	0.000	0.102	0.371	0.640	0.909	1.177	1.446	1.715	1.983
11-19	0.000	0.184	0.453	0.722	0.991	1.259	1.528	1.797	2.065
20-24	0.000	0.242	0.511	0.779	1.048	1.317	1.585	1.854	2.123
25-29	0.014	0.283	0.552	0.820	1.089	1.358	1.626	1.895	2.164
30-34	0.055	0.324	0.593	0.861	1.130	1.399	1.667	1.936	2.205
35-39	0.096	0.365	0.634	0.902	1.171	1.440	1.708	1.977	2.246
40-44	0.137	0.406	0.675	0.943	1.212	1.481	1.749	2.018	2.287
45-49	0.178	0.447	0.716	0.984	1.253	1.522	1.790	2.059	2.328
50-54	0.219	0.488	0.757	1.025	1.294	1.563	1.831	2.100	2.369
55-59	0.260	0.529	0.798	1.066	1.335	1.604	1.872	2.141	2.410
60-64	0.301	0.570	0.839	1.107	1.376	1.645	1.913	2.182	2.451
65-69	0.342	0.611	0.880	1.148	1.416	1.686	1.954	2.223	2.492
70-74	0.383	0.652	0.921	1.189	1.458	1.727	1.995	2.264	2.533
75-79	0.424	0.693	0.962	1.230	1.499	1.768	2.036	2.305	2.574
80-84	0.465	0.734	1.003	1.271	1.540	1.809	2.077	2.346	2.615
85-90	0.506	0.775	1.044	1.312	1.581	1.850	2.118	2.387	2.656
90-100	0.572	0.840	1.109	1.378	1.647	1.915	2.184	2.453	2.721

[a]Outlined portions of table show the range of actual data.

Table 6

SLASH TYPE: Jack pine mixedwood

DESCRIPTION: The jack pine climax slash type is recognized by its slash species mixture of jack pine, spruce, balsam fir, aspen and white birch in varying amounts. The preharvest forest on such a site would be recognized easily as an overmature jack pine forest with a spruce and balsam fir understory.

(a). Estimation of slash consumption (kg/m²) for jack pine climax slash pieces 0-6.99 cm in diameter.[a]

BUI	Preburn slash loading (kg/m²)								
	0-0.99	1.0-1.49	1.5-1.99	2.0-2.49	2.5-2.99	3.0-3.49	3.5-3.99	4.0-4.49	4.5-5.99
0-10	0,251	0.945	1.408	1.370	2.333	2.796	3.259	3.722	4.184
11-19	0.385	1.079	1.542	2.004	2.467	2.930	3.393	3.856	4.318
20-24	0.478	1.173	1.634	2.098	2.561	3.024	3.487	3.949	4.412
25-29	0.545	1.240	1.701	2.165	2.628	3.091	3.554	4.016	4.479
30-34	0.612	1.307	1.768	2.232	2.695	3.158	3.621	4.083	4.546
35-39	0.679	1.374	1.835	2.299	2.762	3.225	3.688	4.150	4.613
40-44	0.746	1.441	1.902	2.366	2.829	3.292	3.755	4.217	4.680
45-49	0.813	1.499	1.969	2.433	2.896	3.359	3.822	4.284	4.747
50-54	0.880	1.499	1.999	2.499	2.963	3.246	3.889	4.351	4.814
55-59	0.947	1.499	1.999	2.499	2.999	3.493	3.956	4.418	4.881
60-64	0.999	1.499	1.999	2.499	2.999	3.499	3.999	4.485	4.948
65-69	0.999	1.499	1.999	2.499	2.999	3.499	3.999	4.499	4.999
70-74	0.999	1.499	1.999	2.499	2.999	3.499	3.999	4.499	4.999
75-79	0.999	1.499	1.999	2.499	2.999	3.499	3.999	4.499	4.999
80-84	0.999	1.499	1.999	2.499	2.999	3.499	3.999	4.499	4.999
85-89	0.999	1.499	1.999	2.499	2.999	3.499	3.999	4.499	4.999
90-100	0.999	1.499	1.999	2.499	2.999	3.499	3.999	4.499	4.999

(continued)

Table 6 (concluded)

(b). Estimation of slash consumption (kg/m²) for jack pine climax slash pieces 7.0 cm or more in diameter.[a]

BUI	Preburn slash loading (kg/m²)								
	0-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	5.0-5.99	6.0-6.99	7.0-7.99	8.0-8.99
0-10	0.000	0.119	0.386	0.653	0.920	1.187	1.454	1.721	1.988
11-19	0.114	0.381	0.648	0.915	1.182	1.449	1.716	1.983	2.250
20-24	0.298	0.565	0.832	1.098	1.365	1.632	1.899	2.166	2.433
25-29	0.429	0.696	0.963	1.229	1.496	1.763	2.030	2.297	2.564
30-34	0.560	0.827	1.094	1.360	1.627	1.894	2.161	2.428	2.695
35-39	0.681	0.958	1.225	1.491	.1758	2.025	2.292	2.559	2.826
40-44	0.822	1.089	1.356	1.622	1.889	2.156	2.423	2.690	2.957
45-49	0.953	1.220	1.487	1.753	2.020	2.287	2.554	2.821	3.088
50-54	0.999	1.351	1.618	1.884	2.151	2.418	2.685	2.952	3.219
55-59	0.999	1.482	1.749	2.015	2.282	2.549	2.816	3.083	3.350
60-64	0.999	1.613	1.880	2.146	2.413	2.680	2.947	3.214	3.481
65-69	0.999	1.744	2.011	2.277	2.544	2.811	3.078	3.345	3.612
70-74	0.999	1.875	2.142	2.408	2.675	2.942	3.209	3.476	3.743
75-79	0.999	1.999	2.273	2.539	2.806	3.703	3.340	3.607	3.874
80-84	0.999	1.999	2.404	2.670	2.937	3.204	3.471	3.738	4.005
85-89	0.999	1.999	2.535	2.801	3.068	3.335	2.602	3.869	4.136
90-100	0.999	1.999	2.744	3.011	3.278	3.545	3.812	4.079	4.346

[a]Outlined portions of table show the range of actual data.

Table 7

SLASH TYPE: Lowland black spruce

DESCRIPTION: Spruce slash consists of the main residue left behind by harvesting on this site. Generally this site is wet with ground water level sometimes near the surface. Often feather mosses and sphagnum mosses are dominant as ground cover.

(a). Estimation of slash consumption (kg/m^2) for lowland spruce slash pieces 0-6.99 cm in diameter.[a]

	Preburn slash loading (kg/m^2)								
BUI	0-0.99	1.0-1.49	1.5-1.99	2.0-2.49	2.5-2.99	3.0-3.49	3.5-3.99	4.0-4.49	4.5-4.99
0-10	0.000	0.618	1.095	1.571	2.047	2.524	3.000	3.476	3.952
11-19	0.000	0.706	1.183	1.659	2.135	2.612	3.088	3.564	4.040
20-24	0.053	0.768	1.244	1.721	2.197	2.673	3.149	3.626	4.102
25-29	0.097	0.812	1.288	1.765	2.241	2.717	3.193	3.670	4.146
30-34	0.141	0.856	1.332	1.809	2.285	2.761	3.237	3.714	4.190
35-39	0.185	0.900	1.376	1.853	2.329	2.805	3.281	3.758	4.234
40-44	0.229	0.944	1.420	1.897	2.373	2.849	3.325	3.802	4.278
45-49	0.273	0.988	1.464	1.941	2.417	2.893	3.369	3.846	4.322
50-54	0.317	1.032	1.508	1.985	2.461	2.937	3.413	3.890	4.366
55-59	0.361	1.076	1.552	2.029	2.505	2.981	3.457	3.934	4.410
60-64	0.405	1.120	1.596	2.073	2.549	3.025	3.501	3.978	4.454
65-69	0.449	1.164	1.640	2.117	2.593	3.069	3.545	4.022	4.498
70-74	0.493	1.208	1.684.	2.161	2.637	3.113	3.589	4.066	4.542
75-79	0.537	1.252	1.728	2.205	2.681	3.157	3.633	4.110	4.586
80-84	0.581	1.296	1.772	2.249	2.725	3.201	3.677	4.154	4.630
85-89	0.625	1.340	1.816	2.293	2.769	3.245	3.721	4.198	4.674
90-100	0.696	1.410	1.887	2.363	2.839	3.316	3.792	4.268	4.744

(continued)

Table 7 (concluded)

(b). Estimation of slash consumption (kg/m^2) for lowland spruce slash pieces 7.0 cm or more in diameter.

	Preburn slash loading (kg/m^2)								
BUI	0-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	5.0-5.99	6.0-6.99	7.0-7.99	8.0-8.99
0-10	0.000	0.243	0.489	0.734	0.979	1.225	1.470	1.716	1.961
11-19	0.052	0.297	0.543	0.788	1.033	1.279	1.524	1.770	2.015
20-24	0.090	0.335	0.580	0.826	1.071	1.317	1.562	1.807	2.053
25-29	0.117	0.362	0.607	0.853	1.098	1.344	1.589	1.834	2.080
30-34	0.144	0.389	0.634	0.880	1.125	1.371	1.616	1.861	2.107
35-39	0.171	0.416	0.661	0.907	1.152	1.398	1.643	1.888	2.134
40-44	0.198	0.443	0.688	0.934	1.179	1.425	1.670	1.915	2.161
45-49	0.225	0.470	0.715	0.961	1.206	1.452	1.697	1.942	2.188
50-54	0.252	0.497	0.742	0.988	1.233	1.479	1.724	1.969	2.215
55-59	0.279	0.524	0.769	1.015	1.260	1.506	1.751	1.996	2.242
60-64	0.306	0.551	0.796	1.042	1.287	1.533	1.778	2.023	2.269
65-69	0.333	0.578	0.823	1.069	1.314	1.560	1.805	2.050	2.296
70-74	0.360	0.605	0.850	1.096	1.341	1.587	1.832	2.077	2.323
75-79	0.387	0.632	0.877	1.123	1.368	1.614	1.859	2.104	2.350
80-84	0.414	0.659	0.904	1.150	1.395	1.641	1.886	2.131	2.377
85-89	0.441	0.686	0.931	1.177	1.422	1.668	1.913	2.158	2.404
90-100	0.484	0.729	0.975	1.220	1.465	1.711	1.956	2.202	2.447

[a] Outlined portions of table show the range of actual data.

Table 8

SLASH TYPE: Upland spruce

DESCRIPTION: Upland spruce slash areas are the result of harvesting in the upland black spruce and boreal mixedwood forest types. Slash species consist mainly of spruce, fir, aspen, and white birch. Usually the duff layer is less than 20 cm deep.

(a). Estimation[a] of slash consumption (kg/m^2) for upland spruce slash pieces 0-6.99 cm in diameter.

	Preburn slash loading (kg/m^2)								
BUI	0-0.99	1.0-1.49	1.5-1.99	2.0-2.49	2.5-2.99	3.0-3.49	3.5-3.99	4.0-4.49	4.5-4.99
0-10	0.000	0.561	0.969	1.377	1.785	2.193	2.601	3.009	3.417
11-19	0.083	0.695	1.103	1.511	1.919	2.327	2.735	3.143	3.551
20-24	0.177	0.789	1.197	1.605	2.013	2.421	2.829	3.236	3.644
25-29	0.244	0.856	1.264	1.672	2.080	2.488	2.896	3.303	3.711
30-34	0.311	0.923	1.331	1.739	2.147	2.555	2.963	3.370	3.778
35-39	0.378	0.990	1.398	1.806	2.214	2.622	3.030	3.437	3.845
40-44	0.445	1.057	1.465	1.873	2.281	2.689	3.097	3.504	3.912
45-49	0.512	1.124	1.532	1.940	2.348	2.756	3.164	3.571	3.979
50-54	0.579	1.191	1.599	2.007	2.415	2.823	3.231	3.638	4.046
55-59	0.646	1.258	1.666	2.074	2.482	2.890	3.298	3.705	4.113
60-64	0.713	1.325	1.733	2.141	2.549	2.957	3.365	3.772	4.180
65-69	0.780	1.392	1.800	2.208	2.616	3.024	3.432	3.839	4.247
70-74	0.847	1.459	1.867	2.275	2.683	3.091	3.499	3.906	4.314
75-79	0.914	1.499	1.934	2.342	2.750	3.158	3.566	3.973	4.381
80-84	0.981	1.499	1.999	2.409	2.817	3.225	3.633	4.040	4.448
85-89	0.999	1.499	1.999	2.476	2.884	3.292	3.700	4.107	4.515
90-100	0.999	1.499	1.999	2.499	2.991	3.399	3.807	4.215	4.623

(continued)

Table 8 (concluded)

(b). Estimation of slash consumption (kg/m^2) for upland spruce slash pieces 7.0 cm or more in diameter.[a]

	Preburn slash loading (kg/m^2)								
BUI	0-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	5.0-5.99	6.0-6.99	7.0-7.99	8.0-8.99
0-10	0.198	0.389	0.581	0.772	0.963	1.155	1.346	1.538	1.729
11-19	0.328	0.519	0.711	0.902	1.093	1.285	1.476	1.668	1.859
20-24	0.419	0.610	0.802	0.993	1.184	1.376	1.567	1.759	1.950
25-29	0.484	0.675	0.867	1.058	1.249	1.441	1.632	1.824	2.015
30-34	0.549	0.740	0.932	1.123	1.314	1.506	1.697	1.889	2.080
35-39	0.614	0.805	0.997	1.188	1.379	1.571	1.762	1.954	2.145
40-44	0.679	0.870	1.062	1.253	1.444	1.636	1.827	2.019	2.210
45-49	0.744	0.935	1.127	1.318	1.509	1.701	1.892	2.084	2.275
50-54	0.809	1.000	1.192	1.383	1.574	1.766	1.957	2.149	2.340
55-59	0.874	1.065	1.257	1.448	1.639	1.831	2.022	2.214	2.405
60-64	0.939	1.130	1.322	1.513	1.704	1.896	2.087	2.279	2.470
65-69	0.999	1.195	1.387	1.578	1.769	1.961	2.152	2.344	2.535
70-74	0.999	1.260	1.452	1.643	1.834	2.026	2.217	2.409	2.600
75-79	0.999	1.325	1.517	1.708	1.899	2.090	2.282	2.474	2.665
80-84	0.999	1.390	1.582	1.773	1.964	2.156	2.347	2.539	2.730
85-89	0.999	1.455	1.647	1.838	2.029	2.221	2.412	2.604	2.795
90-100	0.999	1.559	1.751	1.942	2.133	2.325	2.516	2.708	2.899

[a]Outlined portions of table show the range of actual data.

Table 9

SLASH TYPE: Balsam fir

DESCRIPTION: This slash type is recognizable by its large balsam fir component. The preharvest stands have generally been killed by spruce budworm. In most cases the balsam fir type has been created by bulldozing over the original forest stand. Spruce, white birch, and jack pine may also make a small contribution to slash loadings.

(a). Estimation of slash consumption (kg/m^2) for balsam fir slash pieces 0-6.99 cm in diameter.[a]

	Preburn slash loading (kg/m^2)								
BUI	0-0.99	1.0-1.49	1.5-1.99	2.0-2.49	2.5-2.99	3.0-3.49	3.5-3.99	4.0-4.49	4.5-4.99
0-100	0-0.999	1.0-1.499	1.5-1.999	2.0-2.499	2.5-2.999	3.0-3.499	3.5-3.999	4.0-4.499	4.5-4.999

(b). Estimates of slash consumption (kg/m^2) for balsam fir slash pieces 7.0 cm or more in diameter.[a]

	Preburn slash loading (kg/m^2)								
BUI	0-0.99	1.0-1.99	2.0-2.99	3.0-3.99	4.0-4.99	5.0-5.99	6.0-6.99	7.0-7.99	8.0-8.99
0-10	0.000	0.000	0.000	0.000	0.367	0.953	1.539	2.126	2.712
11-19	0.000	0.000	0.033	0.619	1.205	1.791	2.377	2.964	3.550
20-24	0.000	0.033	0.619	1.205	1.792	2.378	2.964	3.550	4.136
25-29	0.000	0.452	1.038	1.624	2.211	2.797	3.383	3.969	4.555
30-34	0.285	0.871	1.457	2.043	2.630	3.216	3.802	4.388	4.974
35-39	0.704	1.290	1.876	2.462	3.049	3.635	4.221	4.807	5.393
40-44	0.999	1.709	2.295	2.881	3.468	4.054	4.640	5.226	5.812
45-49	0.999	1.999	2.714	3.300	3.887	4.473	5.059	5.645	6.231
50-54	0.999	1.999	2.999	3.719	4.306	4.892	5.478	6.064	6.650
55-59	0.999	1.999	2.999	3.999	4.725	5.311	5.897	6.483	7.069
60-64	0.999	1.999	2.999	3.999	4.999	5.730	6.316	6.902	7.488
65-69	0.999	1.999	2.999	3.999	4.999	5.999	6.735	7.321	7.907
70-74	0.999	1.999	2.999	3.999	4.999	5.999	6.999	7.740	8.126
75-79	0.999	1.999	2.999	3.999	4.999	5.999	6.999	7.999	8.745
80-84	0.999	1.999	2.999	3.999	4.999	5.999	6.999	7.999	8.999
85-89	0.999	1.999	2.999	3.999	4.999	5.999	6.999	7.999	8.999
90-100	0.999	1.999	2.999	3.999	4.999	5.999	6.999	7.999	8.999

(continued)

Table 9 (concluded)

	Preburn slash loading (kg/m²)								
BUI	9.0-9.99	10.0-10.99	11.0-11.99	12.0-12.99	13.0-13.99	14.0-14.99	15.0-15.99	16.0-16.99	17.0-17.99
0-10	3.298	3.984	4.470	5.057	5.643	6.229	6.815	7.401	7.988
11-19	4.136	4.722	5.308	5.895	6.481	7.067	7.653	8.239	8.826
20-24	4.723	5.309	5.895	6.481	7.067	7.654	8.240	8.826	9.412
25-29	5.142	5.728	6.314	6.900	7.486	8.073	8.659	9.243	9.831
30-34	5.561	6.147	6.733	7.319	7.905	8.492	9.078	9.664	10.250
35-39	5.980	6.566	7.152	7.738	8.324	8.911	9.497	10.083	10.669
40-44	6.399	6.985	7.571	8.157	8.743	9.330	9.916	10.502	11.088
45-49	6.818	7.404	7.990	8.576	9.162	9.749	10.335	10.921	11.507
50-54	7.237	7.823	8.409	8.995	9.581	10.168	10.754	11.340	11.926
55-59	7.656	8.242	8.828	9.414	10.000	10.587	11.173	11.759	12.345
60-64	8.075	8.661	9.247	9.833	10.419	11.006	11.592	12.178	12.764
65-69	8.494	9.080	9.666	10.252	10.838	11.425	12.011	12.597	13.183
70-74	8.913	9.499	10.085	10.671	11.257	11.844	12.430	13.016	13.602
75-79	9.332	9.918	10.504	11.090	11.676	12.263	12.849	13.435	14.021
80-84	9.751	10.337	10.923	11.509	12.095	12.682	13.268	13.854	14.440
85-89	9.999	10.756	11.342	11.928	12.514	13.101	13.687	14.273	14.859
90-100	9.999	10.999	11.999	12.599	13.185	13.771	14.357	14.943	15.530

[a]Outlined portions of table show the range of actual data.

Table 10. Relationship between Buildup Index (BUI) and depth of burn (cm) for five slash type sites.[a]

Buildup Index (BUI)	Duff type: Jack pine	Jack pine climax	Lowland spruce	Upland spruce	Balsam fir
0-10	1.58	1.56	1.30	0.00	2.48
11-19	3.11	3.51	2.19	0.00	3.13
20-24	4.17	4.87	2.81	0.00	3.59
25-29	4.93	5.84	3.25	0.76	3.91
30-34	5.69	6.82	3.69	2.39	4.24
35-39	6.45	7.79	4.14	4.01	4.56
40-44	7.21	8.76	4.58	5.63	4.89
45-49	7.98	9.73	5.03	7.25	5.21
50-54	8.74	10.71	5.47	8.87	5.54
55-59	9.50	11.68	5.91	10.50	5.86
60-64	10.26	12.65	6.36	12.12	6.19
65-69	11.02	13.63	6.80	13.74	6.52
70-74	11.78	14.69	7.25	15.36	6.84
75-79	12.54	15.57	7.69	16.98	7.17
80-84	13.30	16.55	8.13	18.61	7.49
85-89	14.06	17.52	8.58	20.23	7.82
90-100	15.18	19.08	9.29	22.82	8.34

[a] Outlined portions of table show the range of actual data.

PRESCRIPTION PREPARATION

One of the more critical portions of the prescribed burn plan is in the development of a suitable prescription for carrying out the prescribed burn and meeting burn objectives. A prescription may require the quantitative estimation of a number of conditions (Table 11) to be met during the day of the prescribed burn. Many of these factors fortunately are correlated with the codes and indices of the CFFWI. This makes prescription preparation easier since only a few codes and indices must be estimated rather than all the conditions outlined in Table 11. In Ontario, OMNR personnel have expressed some concern about the method of making this selection for the prescription.

To obtain the CFFWI codes and indices necessary for the prescribed burn prescription, fire managers should follow the steps listed below:

(1) Consult tables 5-10 to find the range in BUI values required to meet the prescribed burn objectives.

(2) Record the BUI range obtained.

(3) From Table 12, select a spread rate description applicable to your burn and find the corresponding Initial Spread Index (ISI) values for that spread rate.

(4) Record the ISI range obtained.

(5) On the basis of the figures obtained in steps (2) and (4), calculate the required Fire Weather Index (FWI) values from your CFFWI tables (Table 9).

(6) Record the FWI range obtained.

(7) From Table 13, select an ignition rank description applicable to your burn and find the corresponding Fine Fuel Moisture Code (FFMC) range for that ignition rank.

(8) To determine the required wind speed, use the ISI and FFMC values obtained in steps (2) and (4) and read off the required wind speed (km/h) from your CFFWI tables (Table 7). If the wind speed you have found appears too high for your conditions, revise your FFMC range upward and repeat step 5, or revise your ISI range downward in step 3.

(9) Record the FFMC and wind speed values obtained.

(10) Determine the best wind direction for your burn and record it. Both wind speed and direction are dependent on the type of ignition pattern chosen for your burn.

Table 11. Factors which may be used as prescription variables (adapted from Martin 1978).

Weather	Soil
Wind	Moisture
Temperature	Temperature
Relative humidity	
Precipitation	Vegetation
Atmospheric stability	
Sunny or cloudy	Condition
	Moisture content
Fuel	
	Time
Moisture content by size class	
	Seasonal
Load	Diurnal
Height	
Condition	Canadian Forest Fire Weather Index
Fire	Fine Fuel Moisture Code
	Duff Moisture Code
Flame length	Drought Code
Intensity	Initial Spread Index
	Buildup Index
Fire Application	Fire Weather Index
Ignition pattern technique	
Lighting method	

Table 12. Relationship between ISI and rate of spread (adapted from Muraro 1975).

ISI	CLASS[a]	Maximum rate of spread (m/min)[b]	SPREAD RATE
≥ 0	Low	0.0	EXTREMELY SLOW - *Excessive ignition* density is required to obtain *very poor coverage* except in the most concentrated slash. No real spread of fire from ignition piles.
1-2	Low	1.0	SLOW - *Normal ignition* density provides satisfactory coverage in favorable slash areas. Fires may start.
3-4	Moderate	5.5	MODERATELY SLOW - *Normal ignition* density provides *satisfactory coverage in most slash*; areas lacking slash may not be involved.
5	Moderate	7.5	MODERATELY FAST - *Normal ignition* density provides *good coverage in all slash.*
6-7	High	12.0	FAST - *Less than normal ignition* provides *good coverage* involving all fuels.
8-10	High	19.0	VERY FAST - *Less than normal ignition* provides *continuous coverage* in all fuels.
> 10	Extreme	>19.0	EXTREMELY FAST - *Minimal ignition* effort provides *continuous coverage* and involves all fuels.

[a] Ontario Fire Weather Index classes

[b] Values obtained from Stocks and Walker (1972) for jack pine slash fuels.

Table 13. Relationship between FFMC and ease of ignition (adapted from Muraro 1975).

FFMC	CLASS[a]	Fuel moisture content (% O.D.)[b]	IGNITION RANK
< 70	Low	> 31	EXTREMELY DIFFICULT - *Ignition of fuels almost nonexistent.*
71–80	Low	21–30	VERY DIFFICULT - *Persistent effort at favorable locations*[c] yield flames of *low vigor*. Slow moving drip torch provides spotty ignition.
81–82	Moderate	19–20	DIFFICULT - *Some effort at favorable locations* yields flames of *low to moderate vigor*. Slow moving drip torch provides intermittent ignition.
83–84	Moderate	17–18	MODERATELY DIFFICULT - *Some effort at average locations*[d] yields flames of *moderate vigor*. Slow moving drip torch provides continuous ignition.
85–86	Moderate	15–16	MODERATELY EASY - *Little effort at average locations* yields flames of *moderate vigor*. Moderately fast moving drip torch provides continuous ignition.
87–88	High	13–14	EASY - *Little effort at unfavorable locations*[e] yields flames of *moderate to high vigor*. Fast moving drip torch provides continuous ignition.
89–90	High	11–12	VERY EASY - *No effort in unfavorable locations* yields flames of *high vigor*. Very fast moving drip torch provides continuous ignition.
> 90	Extreme	< 11	EXTREMELY EASY - *No effort at unfavorable locations* yields flames of *high vigor*. Adequate ignition rate limited only by rate of drip torch travel.

[a] Ontario Fire Weather Index classes.

[b] Oven-dry fuel moisture expressed as a percentage for slash 0–0.49 cm in diameter.

[c] Favorable locations have a slash loading greater than 2.0 kg/m^2 for slash 0–6.99 cm in diameter.

[d] Average locations have a slash loading of 1.0–2.0 kg/m^2 for slash 0–6.99 cm in diameter.

[e] Unfavorable locations have a slash loading of less than 1.0 kg/m^2 for slash 0–6.99 cm in diameter and may have discontinuous slash coverage.

(11) The historical use of the fire weather prescription in Ontario can be analyzed by means of the PBWX computer program (Martell 1977, 1978) available through the OMNR Aviation and Fire Management Centre[1]. This program can be used to determine how frequently the specific prescription has occurred in the past. Such analysis permits a planner to evaluate the likelihood that the prescription will occur in the future. The variables used in this analysis should include only the FFMC, ISI and BUI. It is impossible to determine the precise probability that the prescription will occur because of the considerable variability in fire weather conditions from year to year[2].

Values for the Duff Moisture Code (DMC), Drought Code (DC), temperature and relative humidity are not a prime consideration in setting burning prescriptions since they can be multi-variable and still achieve the same prescribed burn objectives. To obtain a similar BUI, there are a number of DMC and DC combinations that may be used. This is also true for the FFMC where a number of combinations of temperatures, relative humidity, wind speed and the previous day's FFMC can be used to obtain the same value. It is therefore less meaningful to set these as variables in a prescribed burn prescription. Elimination of these factors in the prescription ensures that the burning period for the particular prescription is effectively increased because there are fewer restraints. Placing prescriptions in range (e.g., BUI = 33-39) also effectively increases the number of burning chances. Example 2 shows how to construct a suitable prescription in jack pine slash.

RESEARCH NEEDS

Further research and analysis of the information presented in this report are required to improve the reliability of results. The number of prescribed burns examined should be expanded for all slash fuel types. This may be done through continued monitoring by GLFRC personnel, and through collection of data and storage in a data bank by OMNR personnel.

With increased use of computer technology within the OMNR fire management operation, future work should be aimed at prediction of slash consumption on the basis of the five diameter size classes now used in documenting slash fuels between 0 cm and 6.99 cm in Ontario (McRae et al. 1979). Because of the great variability in diameters for slash

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[1]P.O. Box 310, Sault Ste. Marie, Ontario. P6A 5L8

[2]D.L. Martell, Dec. 17, 1979. pers. comm.

Example 2. Estimating prescription variables for the prescribed burn plan.

In example 1, mineral soil exposure on a site which had a preburn duff depth of 4.5 cm was required for preparing a seedbed by prescribed burning. It was determined that a BUI of 25-29 was necessary to obtain the required duff removal (depth of burn).

Since fire crews of this particular district are not experienced in prescribed burning, it is decided that a maximum ISI of 5 (from Table 12) is sufficient for rapid completion of the prescribed burn with relative safety. A realistic prescription is set with an ISI range of 3-5.

The range in ISI and BUI values allows for a FWI range of 6-10 as found in Table 9 of the CFFWI tables.

To permit easy ignition of the slash by the fire crews and to ensure easy control, a moderate FFMC range (85-88) is chosen for the burn from Table 13.

The ISI and FFMC values determined thus far were used to obtain a range in wind speed that would satisfy the ISI and FFMC values. Table 7 of the CFFWI tables was used to obtain the following wind speed values:

FFMC	Wind speed (km/h)
85	5 - 18
86	3 - 15
87	0 - 13
88	0 - 10

To complete the prescription for this burn, planners set a wind direction of southwest as a requirement because of the ignition pattern chosen and forest values to be saved around the southwestern portion of the prescribed burn site. An unstable atmospheric condition was also stipulated to ensure adequate smoke dispersal.

pieces 7.0 cm and larger, computer technology could provide a one-on-one basis for estimating slash consumption by combining species and diameter size of the preburn slash piece and relating the product to the BUI in a program. The one-on-one concept of correlating individual consumption using the same fuel piece is important for larger slash pieces since consumption rates can be vastly different for pieces of similar diameter but of different species type (e.g., balsam fir and poplar), and for pieces of the same species that differ greatly in diameter size.

LITERATURE CITED

ANON. 1978. Canadian Forest Fire Weather Index tables. Dep. Environ., Can. For. Serv., Ottawa, Ont. For. Tech. Rep. 25. 47 p.

MARTELL, D.L. 1977. Analyzing the past occurrence of prescribed burn fire weather prescriptions. Ont. Min. Nat. Resour., Sault Ste. Marie, Ont. Fire Manage. Bull. No. 59. 3 p.

MARTELL, D.L. 1978. The use of historical fire weather data for prescribed burn planning. For. Chron. 54:96-98.

MARTIN, R.E. 1978. Prescribed burning: decisions, prescription, strategies. Paper presented at the 5th Joint AMS-SAF Fire and Forest Meteorology Conference (March 14-16, Atlantic City, N.J.). p. 94-95.

McRAE, D.J., ALEXANDER, M.E. and STOCKS, B.J. 1979. Measurement and description of fuels and fire behavior on prescribed burns: a handbook. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-287. 60 p.

MURARO, S.J. 1975. Prescribed fire predictor. Can. For. Serv., Victoria, B.C. (chart).

STOCKS, B.J. 1972. A burning index for jack pine logging slash. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Suppl. ONT-1 to Can. For. Fire Danger Rating System.

STOCKS, B.J. and WALKER, J.D. 1972. Fire behavior and fuel consumption in jack pine slash in Ontario. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Inf. Rep. O-X-169. 19 p.